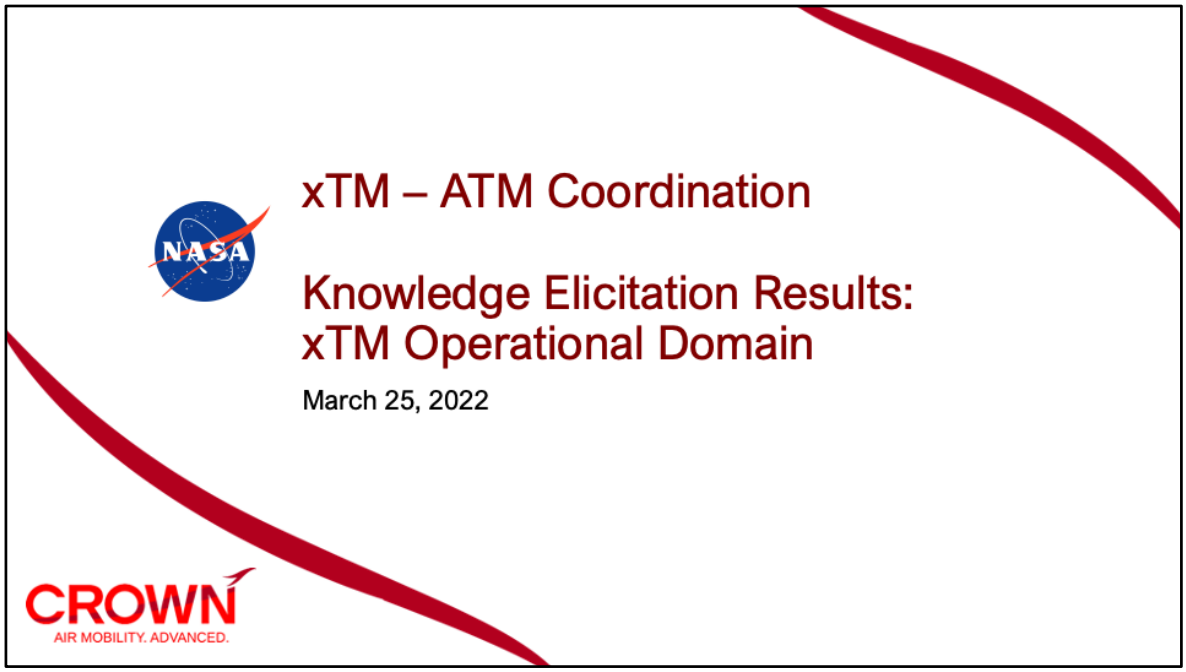
xTM – ATM Coordination
Knowledge Elicitation Results:
xTM Operational Domain
March 25, 2022
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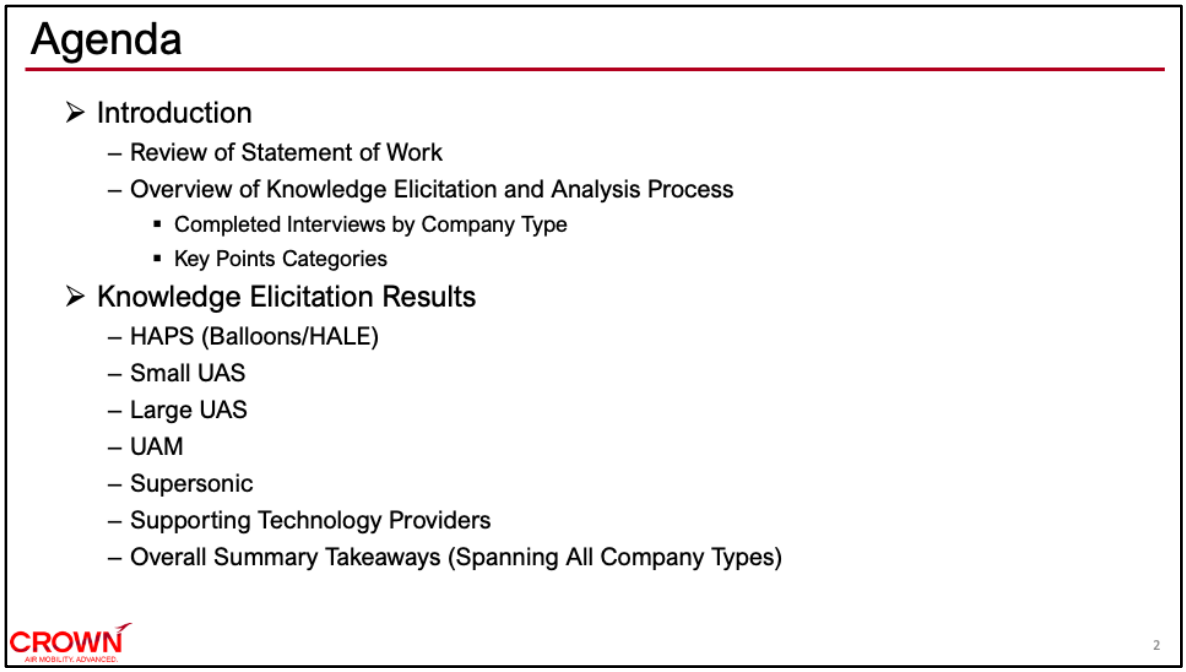

Crown Consulting Inc. has been tasked by NASA to elicit information from operators, vehicle manufacturers, and service suppliers on the expected xTM-ATC coordination. For this presentation, first, we will do a quick introduction for what NASA asked us to do and what our process was to complete that tasking. The second part of the presentation will go through our results which are broken up into the participant company types that we interviewed. Our results are very heterogeneous; we did summarize, but the more detailed results are what are most interesting. The company types are HAPS (Balloons/HALE), sUAS, Large UAS, UAM, Supersonics, and Supporting Technology Providers.

Introduction

Statement of Work (1 of 2)

- **Background:** The Extensible Traffic Management (xTM) system will likely need to interact with the existing traffic management environment. For some entrants, such as small UASs, this interaction will be minimal. Other new entrants such as unmanned cargo operations will take place largely within the same airspace as traditional operations, and will require more significant changes, to enable safe access to Air Traffic Control (ATC) services.
- **Objectives:** Elicit knowledge to understand and define the nature of interactions that are anticipated to take place between the ATC and airspace users (vehicles and operators). The use cases will include UAM, small UASs, HALE, supersonics, balloons, and commercial space (optional).

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Crown Consulting Inc. was tasked by NASA to interface with industry and elicit knowledge regarding the coordination that is expected to take place for ATC and the new airspace users. You can see the types of operators we were asked to focus on: HAPS, sUAS, Large UAS, UAM, Supersonics, and Supporting Technology Providers.

Statement of Work (2 of 2)

Tasks:

- Knowledge elicitation with industry partners in the xTM operations domain to identify expected interactions between ATCs and the xTM vehicles and systems and associated challenges. New entrant vehicles include: UAM, sUAS, HALE, Supersonics, Balloons, Space Commercial (optional).
  - Recommendations on research areas for xTM-ATC interactions
- Knowledge elicitation with industry partners in the xTM service supplier domain to identify data exchanges needed from industry perspective within a particular xTM system and across different xTM systems to enable and support interactions with ATC. xTM system includes UAS Service Supplier (USS) network serving small UAS and Providers of Services for Urban Air Mobility (PSU) network serving UAM.
- Presentations, documentation, references

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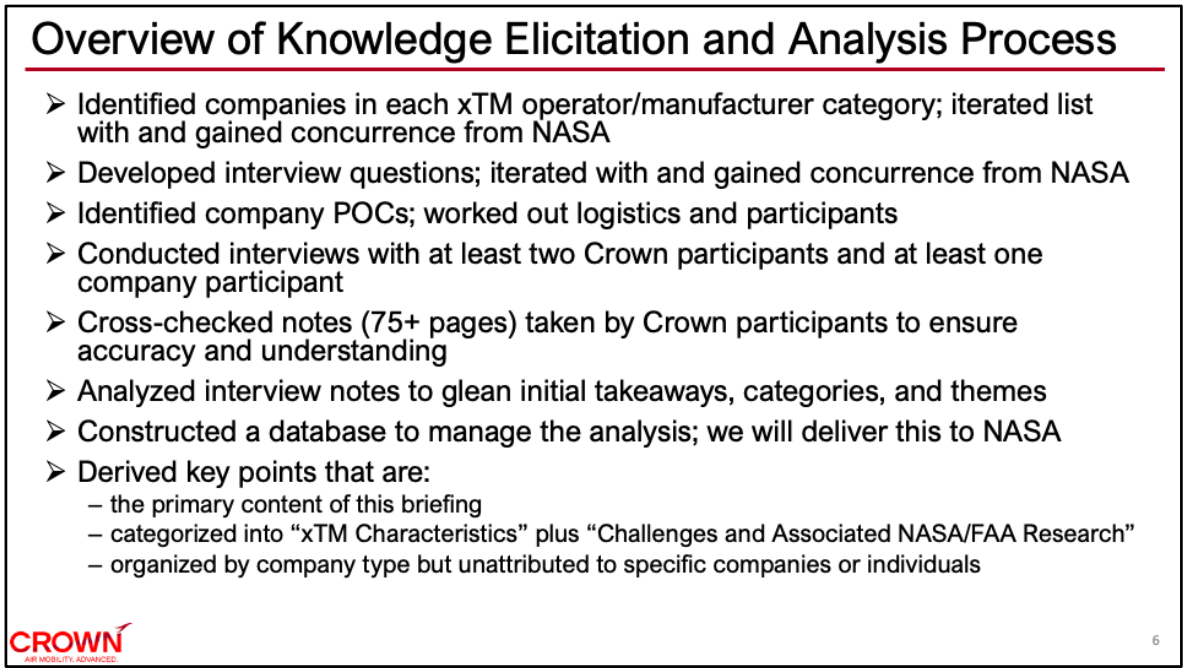
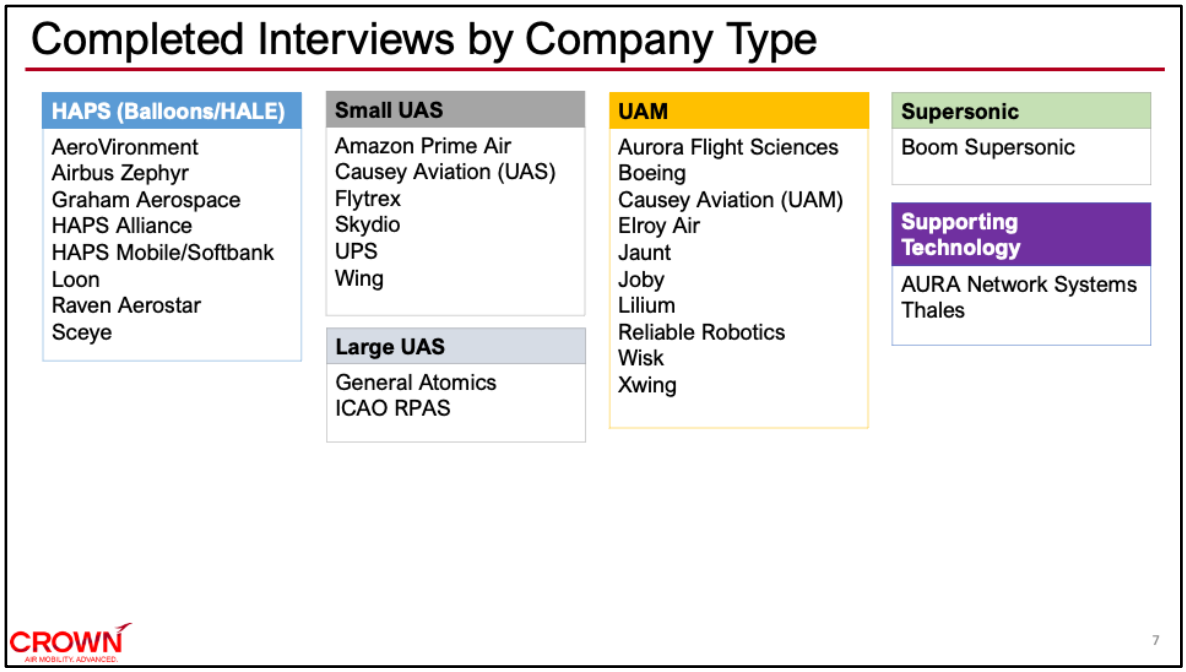
We will also be eliciting knowledge from industry partners in the xTM service suppliers (USSs and PSU)s. The focus for that part is a little different than the operators because we are focused on specific data exchanges. This presentation will only cover the operators/manufacturers domain piece of the knowledge elicitation task, which is why the second bullet is grayed out.



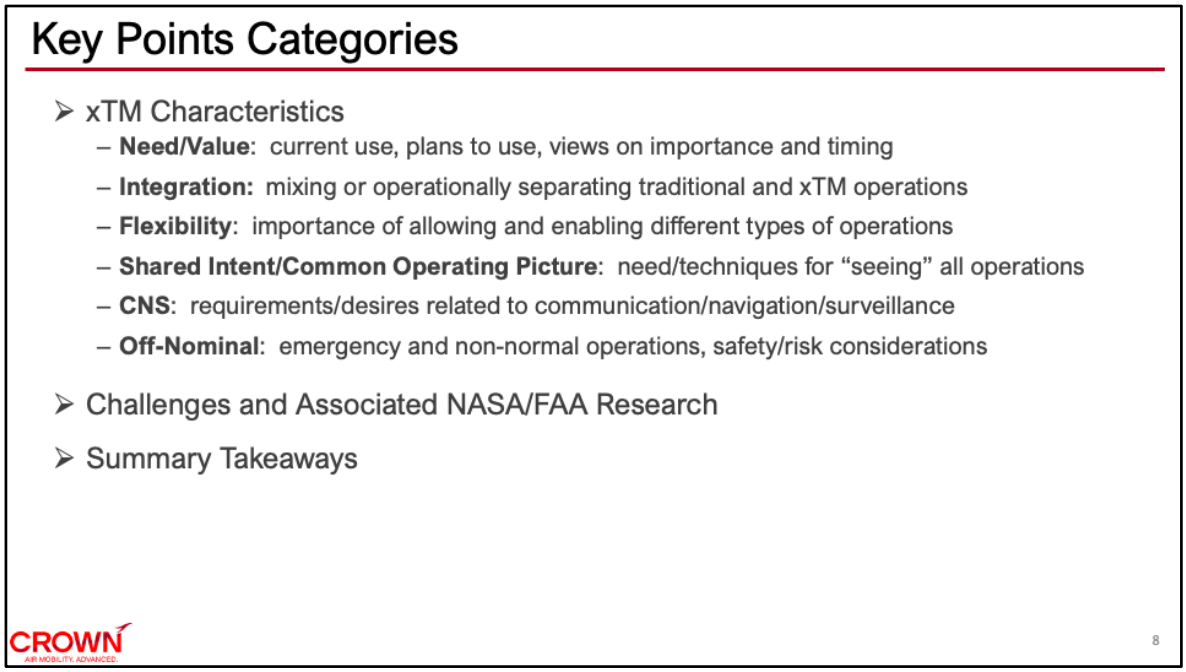
To give an overview of our process, we first had to identify the companies in each of the categories and then iterated on that list with NASA to ensure we were getting good representation across industry. The companies that we talked to were a subset from our master list that we developed and are working from. During that same time, we developed our interview script/questions and iterated on that as well. That was important in the sense that if you look at the first task with knowledge elicitation, what we were asked to do is only described at a high level, so we developed specific questions to draw out more detailed answers. During the interviews, we ensured there were at a minimum 2 Crown staff to take notes and cross check our notes to make sure we were capturing the feedback faithfully.

On the company side, we usually had more than one participant from each company, but in some instances, just one. Once we had the data gathered from the interview phase, we went into the analysis phase and that was important because we had all of this data, but we had to organize the data and pull out the main highlights and takeaways. We constructed a database which will also be a deliverable to NASA,. There is a lot of good data in there, it is processed some but still raw data from the interviews. What we ended up doing was deriving the key points which is the main point of that briefing today. We categorized them into xTM characteristics (which we'll get into two slides from now) and challenges and associated research the industry would like to see NASA and FAA focus on. Our policy was to not attribute the comments to individuals or companies that they represented, that was a way to get more and open honest feedback. The data in this presentation is non attributable, with one exception that we'll talk about on the next slide.



We feel that across the company types we had good representation across the industry and interviewed many of the industry leaders, especially in UAM and HAPS categories. Note, we did not cover military applications because that is something that should be addressed separately. For supersonics, Boom was the only interviewee, and they gave approval for us to share their attributable feedback, so that's the one exception to our non-attribution policy.

The Supporting Technology category is a bit of a misnomer – AURA would be considered Supporting Technology, but Thales is an international conglomerate that does a ton of things so we somewhat arbitrarily put the in this category.

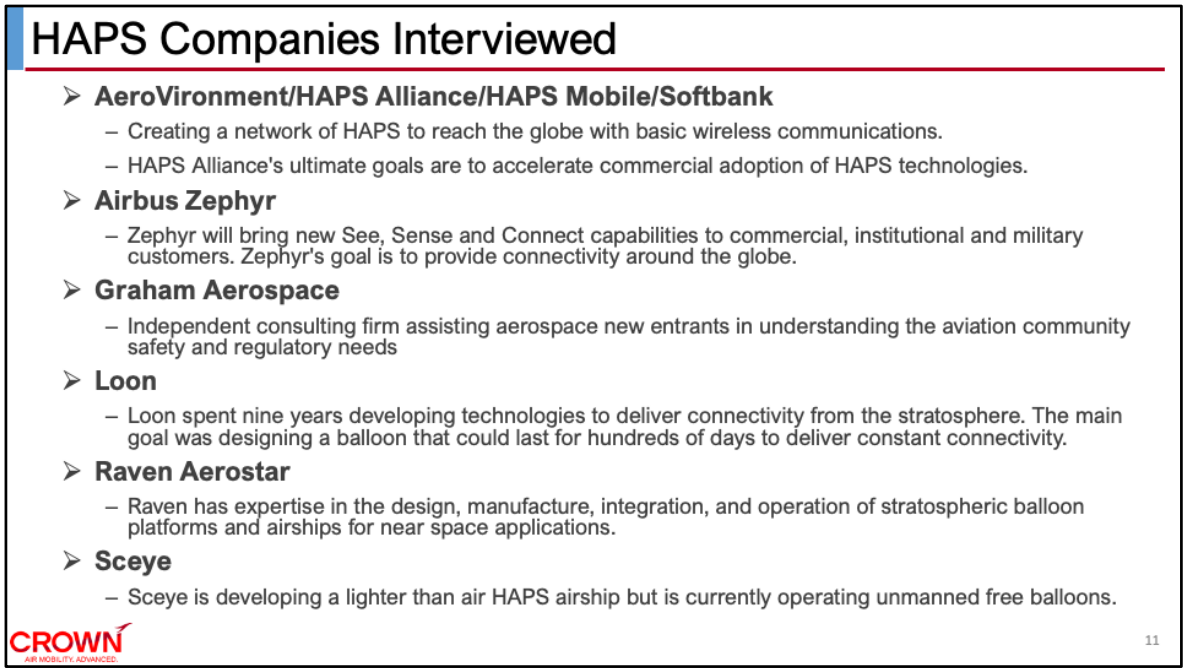


Once we looked at the data, we developed out the keep categories where takeaways emerged. Note, these categories were developed post interviews, based upon what we heard, not in advance – we let the output dictate the categories. For the challenges category, we were originally targeting feedback for NASA but then included the FAA since a lot of the feedback was also applicable to the FAA.

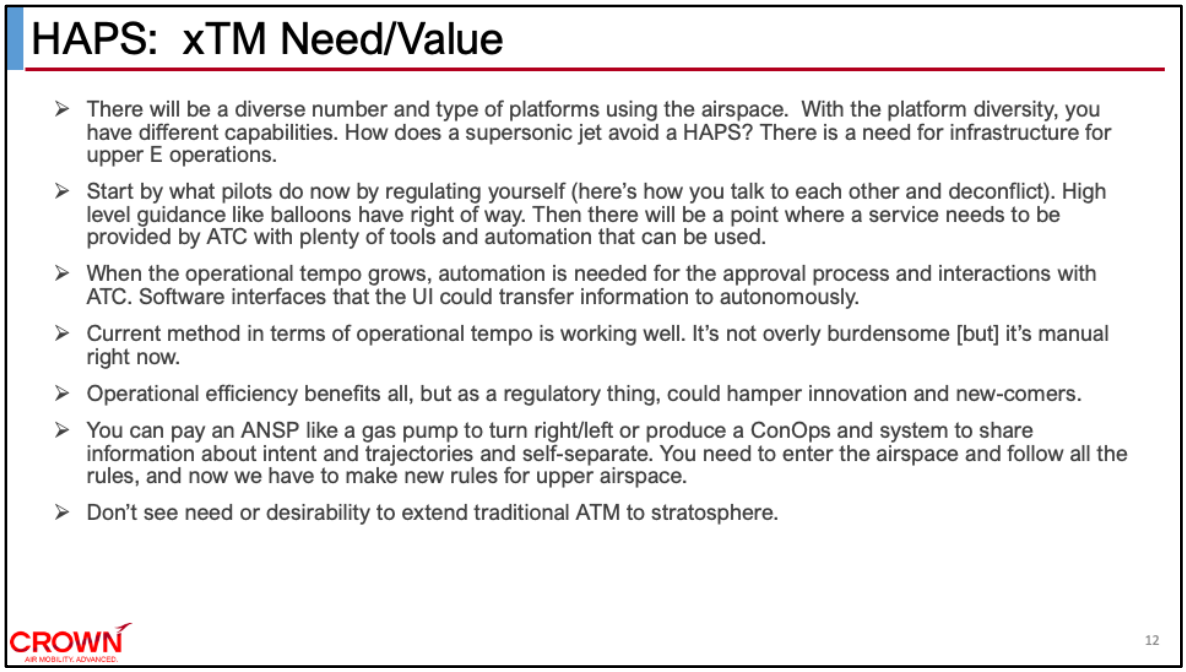
Note that when we talked about "xTM" with the interviewees, they would focus in on whichever "flavor" of xTM that was most pertinent to them. For example, the HAPS community associates xTM with Upper Class E Traffic Management (ETM). Similarly, the UAS community focused on UTM and the UAM community focused on PSUs. That's why we broke up our results by company type because xTM is different for each.

Knowledge Elicitation Results

HAPS (Balloons/HALE)



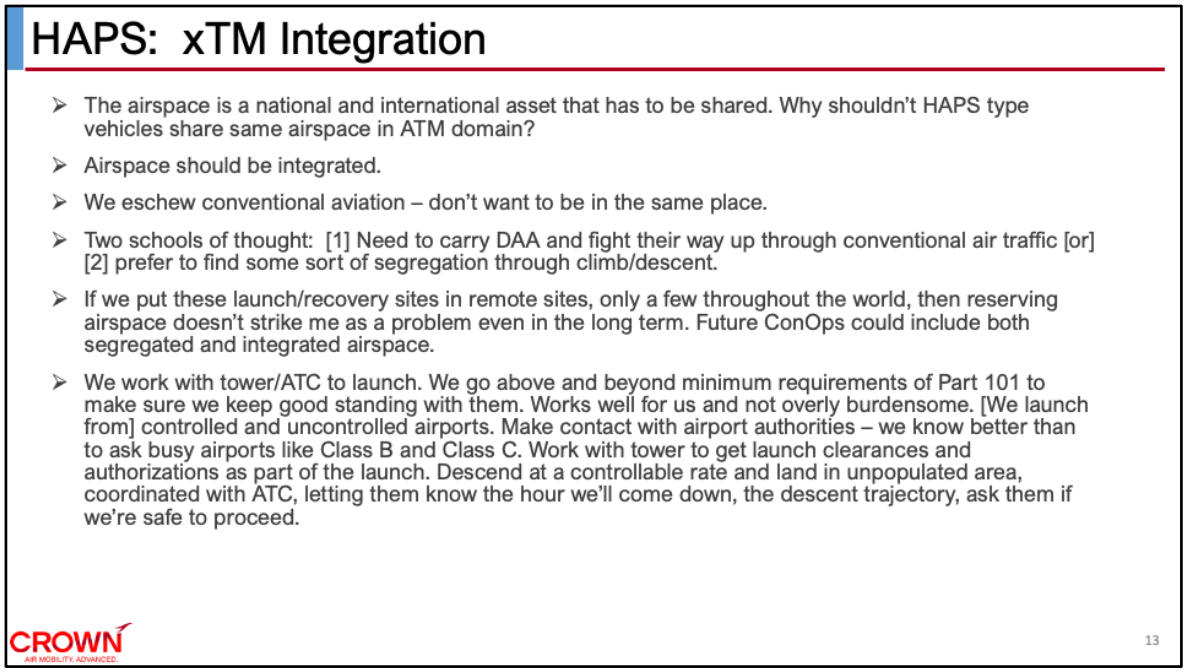
We will present data based upon the types of companies but not in any specific order. First, we will do the HAPS (High Altitude Platform Stations/Systems) companies which covers HALEs and Balloons. We came to understand that HAPS seems to be the preferred term, so we adopted that. We have brief descriptions of each of the companies interviewed at the front of each section for awareness.



In this case, for HAPS, it was mostly focused on ETM. What you see in the bulk of the slide is a series of bullets and each of these are direct quotes from an interviewee; there are brackets where we expanded to clarify things. These quotes are a subset that is representative of the overall comments made and a flavor of what we heard in this category.

HAPS highlighted that there are different users which cause a challenge, so there is a need for infrastructure/rules. As you glance through the feedback from the interviewees, that is the common flavor, everyone agreed they needed a better and organized way to interact in the airspace. There are some quotes that balance that out -- a few statements saying that the current airspace is working fine. Examples include: "We work it out and it is not overly burdensome, but it is manual" and "Traditional ATM shouldn't just be extended up to the stratosphere."

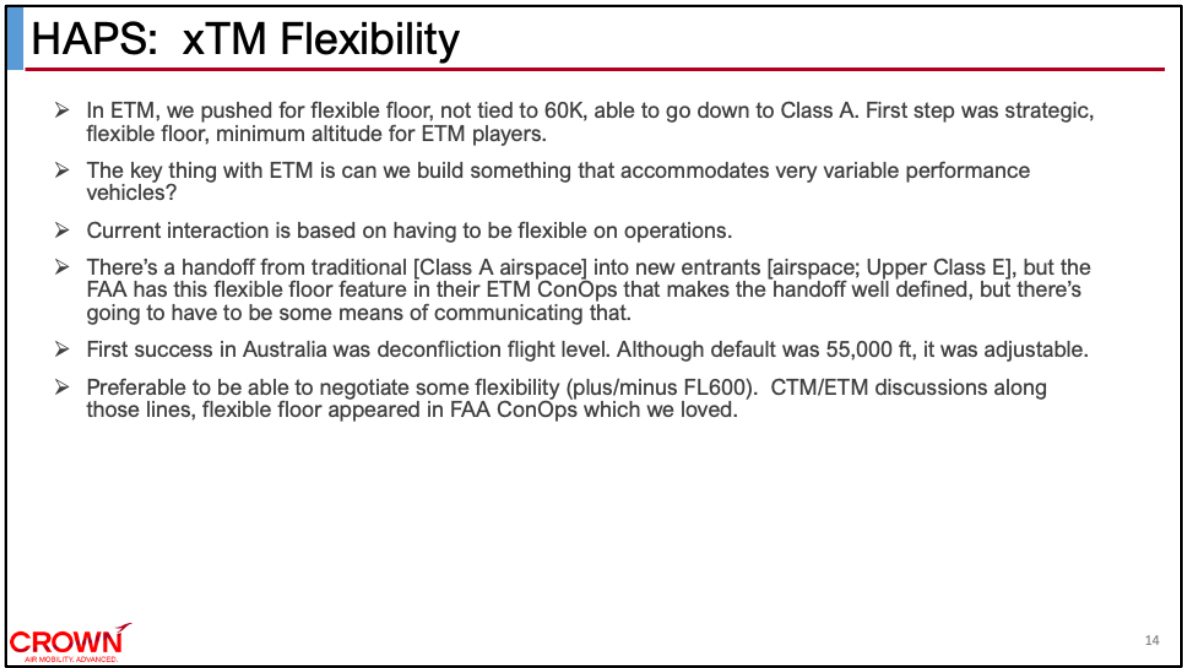
For the quote "pay an ANSP like a gas pump", that is highlighting that if you had a service provider you were buying services from, you would have to pay for a service in some way. The company was saying it as "we don't like that, so instead you can produce a ConOps and a system that gives you the rules and a way to do things up there". Put another way, "you don't need the services provided discretely but instead take care of yourselves where everyone understands how to do business".



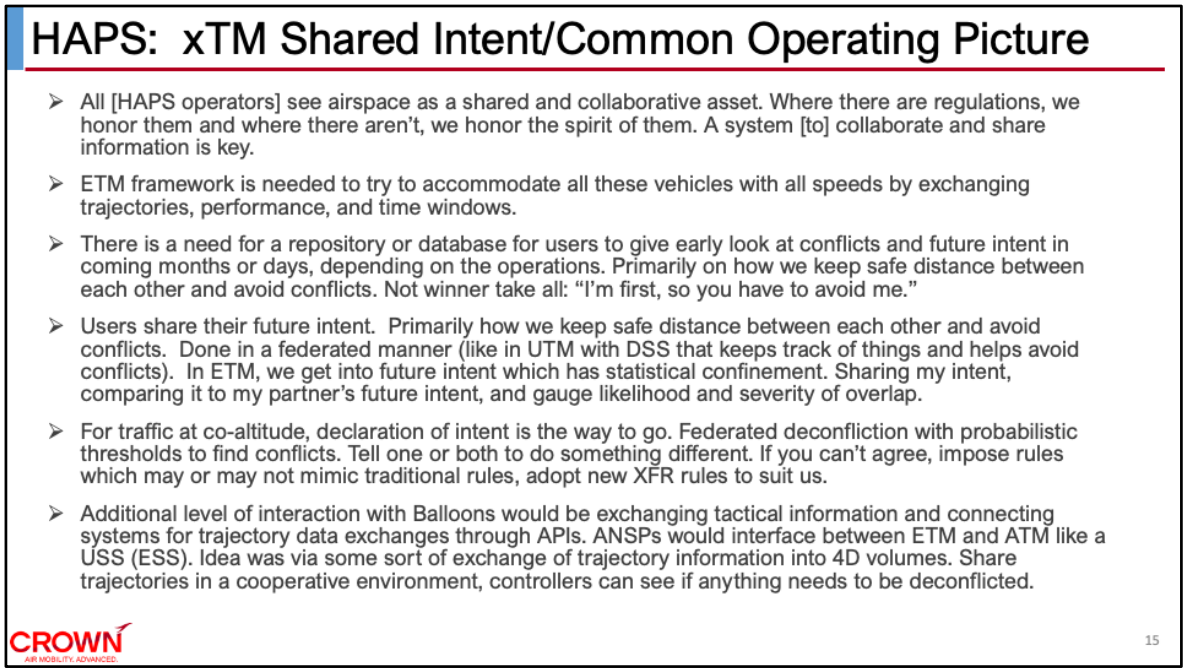
For the xTM characteristics on integration for HAPS, we discussed how the airspace will be shared and used. Responses were a mixed bag. The first couple of comments you see on this chart is regarding sharing it and integrating within the airspace. But then you will see some comments that prefer segregated.

What the companies are really talking about in their comments here is the launch phase. One approach would be to be equipped as you need to with DAA and you get through conventional air traffic, but the other approach would be to find some sort of segregation.

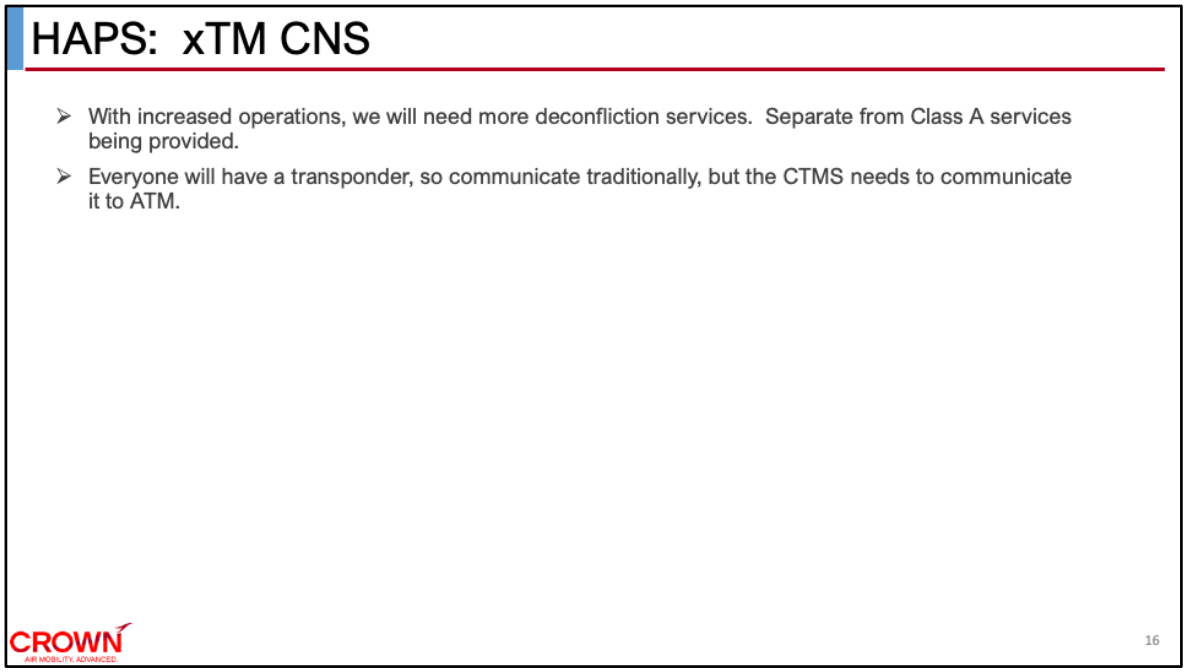
The following comments say that what is currently in place works okay and it doesn't strike that interviewee as a particular problem. The last comment gets into the details for how that company operationalizes it right now, which is tightly integrating and coordinating with ATC.



For xTM characteristics regarding flexibility, they all went to the same place of the concept of having a flexible floor. The idea being that ETM would be for 60,000ft. and above but it would help if that was not locked in stone and there could be flexibility when the operators needed it would be helpful. The remainder of the comments are more or less agreeing with the flexible floor feedback.



Shared intent and common operating picture is our next category that emerged from the interviews. Everyone had agreement that people needed to share their trajectories and intent, which is not a big surprise. People want the system and people to know about each other and not a "winner take all approach" or "I was here first".



For CNS xTM characteristics, there were not a ton of comments but there was the assumption that everyone will have a transponder.

HAPS: xTM Off-Nominal

- In the world of UAM, it is different. Regulators have to face it and look at the risk of what it is, not just traditional manned aircraft risk. FAA wants to start with the existing and take away things. Australia is starting with a clean sheet.
- For deconfliction, [we are] working through proofs of concepts and prototypes for a capability. So, they get the info but don't share so they have responsibility to avoid others.
- In case of failure, anticipated that we would provide best estimate, like from satellite link, ground control algorithms. If we lose link with a vehicle, could still estimate where the vehicle is with growing uncertainty. Balloons are probabilistic anyway so 4D volumes are estimates like hurricane tracks.
- For supersonic, they will need to get out of the way. Worst-case scenario is where you can't be collaborative in the CTMS (I can't see you because I'm moving too fast, and I can't communicate with you).
- We will need to provide a picture for people who don't want to say what they're doing such as military/state aircraft. It's safer than what they do currently.
- The airworthiness problem needs to be 10^{-9} so it never happens.
- Would be better off dealing with some rudimentary cases than worst possible cases. Get basic model right and then perturb it.

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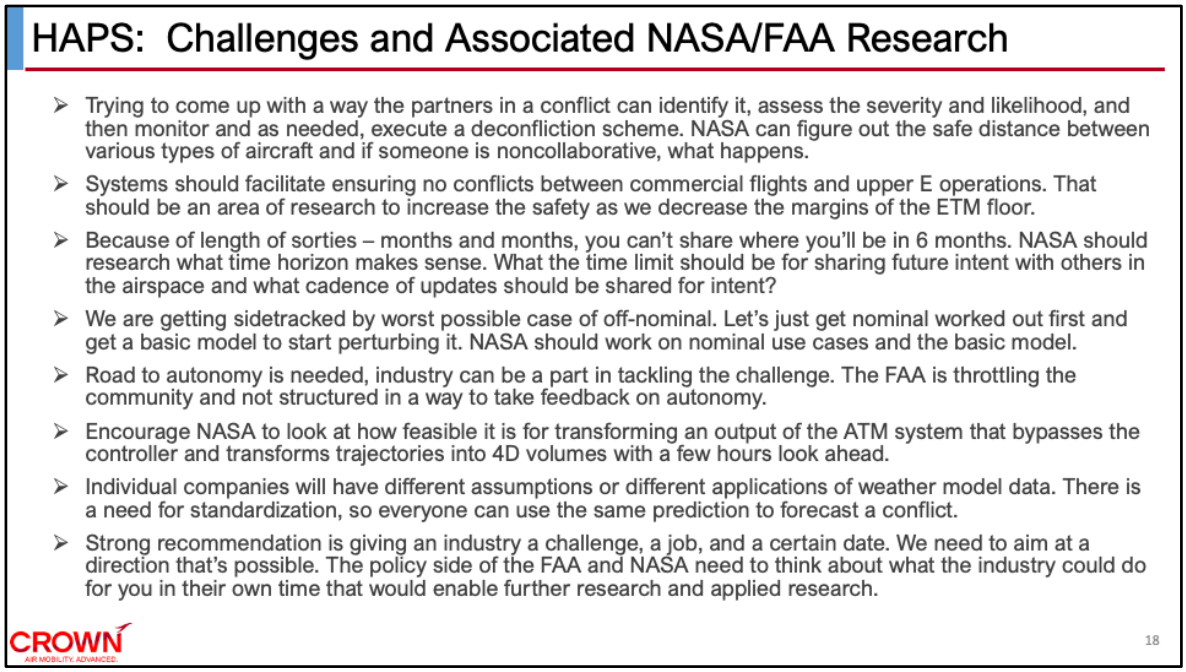
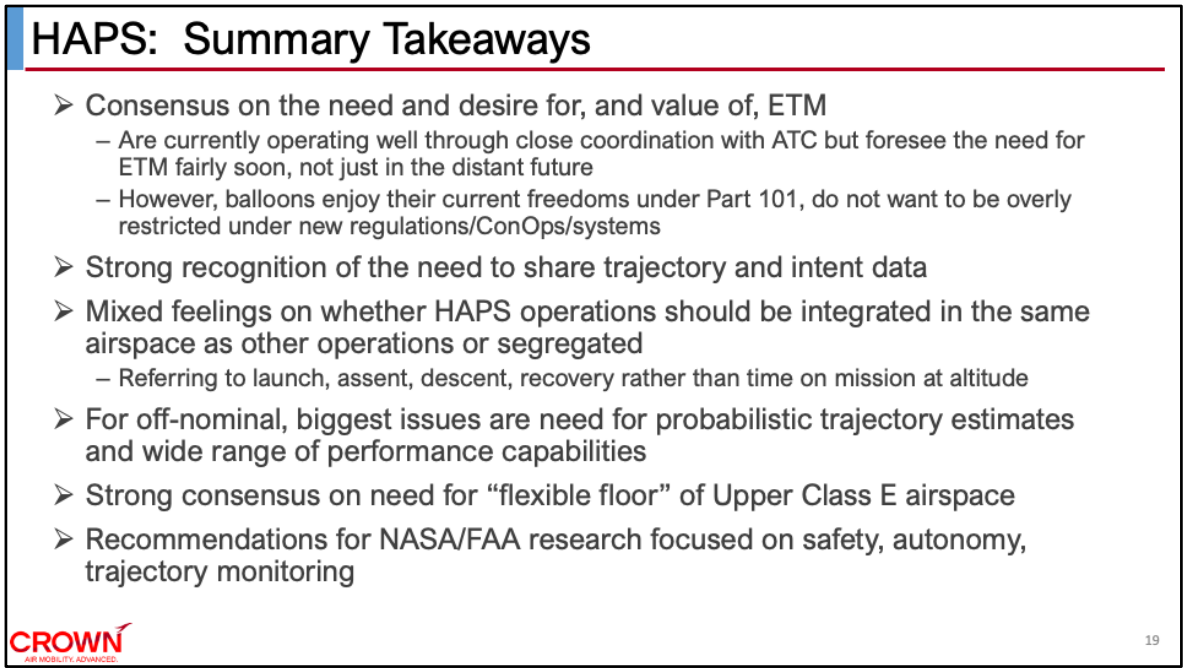
For off nominal xTM characteristics, there were some interesting things mentioned. This scenario for supersonic came up a few times from different people as an example. It is because the fact is that the worst thing is the radical difference in trajectory profiles and speed with the supersonic operations. Things happen so fast so that is what you have to really worry about.



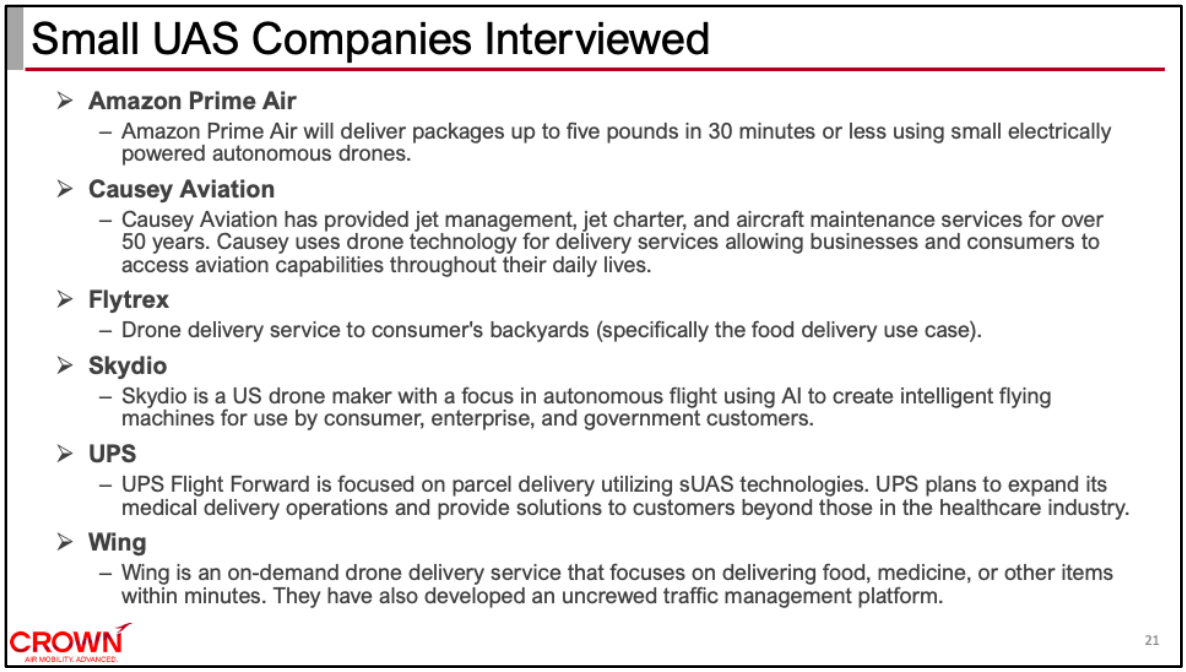
There was a lot of discussion on dealing with conflicts and how you resolve them. We found that it was interesting that they said they understand needing to consider off nominal conditions but said to not focus on the worst case because it is unlikely.

It was in testing that industry said they were there and can help the government if you give a challenge and a timeline associated with it, the government doesn't have to figure everything out. They were emphasizing that if you work with industry, they want to help you within the government tackle the barriers.

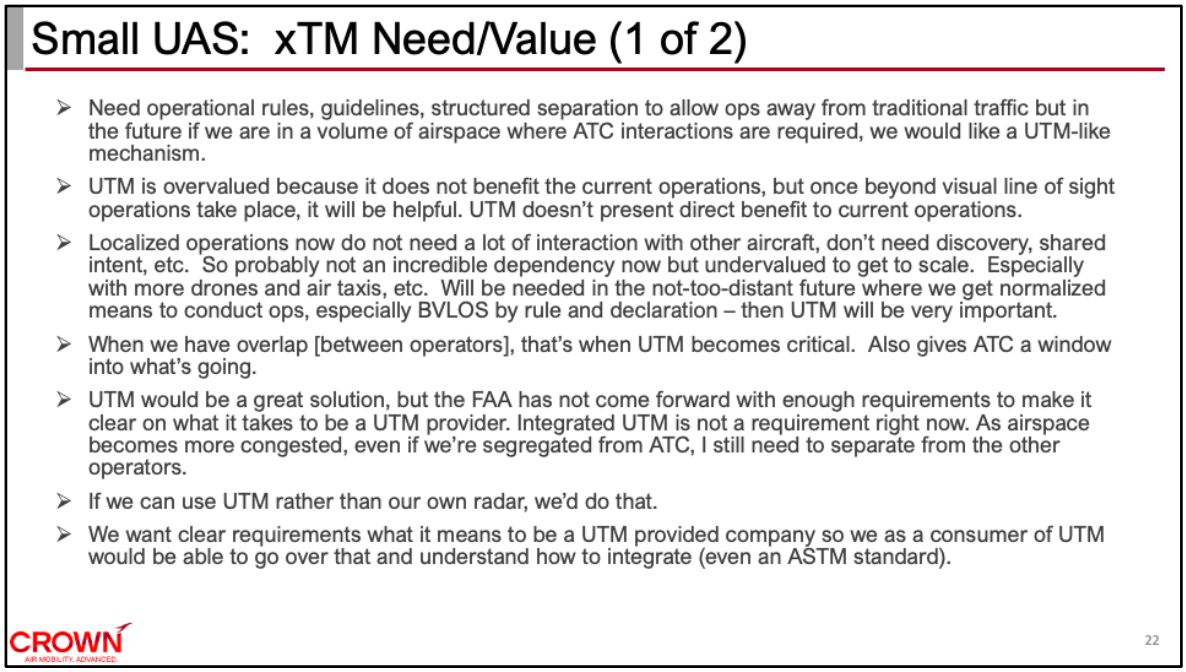


We did summarize takeaways at the end of each company category. To list those out, the free balloons like the way they operate now because Part 101 gives them precedence, so they are not opposed to ETM, but they like how they are operating and that was mentioned. For the shared intent topic, everyone was on board with that, but for the integration aspect, there were mixed feelings which was an aspect highlighted even in the other company categories. We saw quite a few different opinions being expressed around integration.

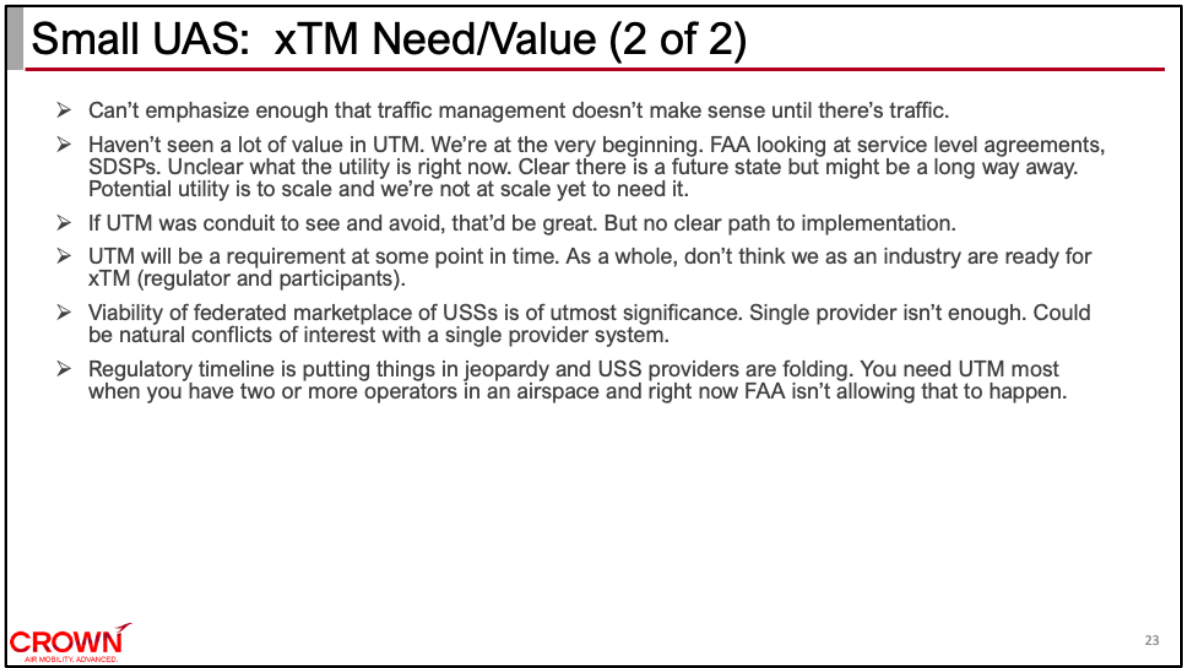

Small UAS



We have brief descriptions of each of the companies interviewed at the front of each section for awareness.



We will dive right into the first area for sUAS regarding the xTM need and value. I will point out a few things. It was a strong statement that right now UTM doesn't benefit the current operations, but when they get to BVLOS, UTM will be needed. They are saying if they are away from traditional traffic, they are in their own realm and okay, but if they are interacting with ATC, then they need something like UTM.



Continuing on the need and value, utility is when they are at scale. What we picked up on a lot, is that they were not thinking UTM was a waste of time, but rather that they were not ready for it or need it yet. Most of the companies are looking at the near term because they need to survive. From their point of view, UTM was far out and not of use currently for operations.

Small UAS: xTM Integration

- Since it's below 400 ft and away from traditional traffic, won't be much interaction with traditional ATC.
- We should not be advocating for segregation where parcels of airspace are inaccessible. Segregation is a four-letter word, don't want airspace cordoned off. With mitigations in place, can coexist.
- Will come a time where you might have more occasion to have mechanisms to conduct ops in volumes of airspace where you'd have to have more interaction with traditional ATC – TRACONs, towers, etc.
- For low altitude drones, they will be segregated by altitude. ATC has made clear they don't want to think about them except at boundaries, like at airports.
- There's temptation to build a separate system but if you look at how it operates, that won't work forever because of the cross-over points. Eventually you'll have to integrate.
- Drones will be segregated except in terminal areas, staying away from other operations so that their need to interact with other vehicles is limited.
- The basic model is staying away from everyone else based on altitudes.
- Segregated airspace might be the easiest thing to do.
- Plan is to maintain segregation with ATC. Currently no interaction with ATC.
- ATC may have requirements such as surveillance and comms, but operations will be segregated.
- Operating in class G and E, in class B, and Mode C veil. Picked Mode C veil because wanted to fly in integrated airspace with ADS-B requirement and situational awareness.

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Like the last category, when we asked about integration, there was a mix of opinions.

Small UAS: xTM Flexibility

- For one to many, possible example is formation flight. In military, squadron of ten aircraft but one lead aircraft guides the others. Maybe a precedent for one to many? Ten RPICs but one dispatcher who handles the clearances and authorizations.

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Small UAS: xTM Shared Intent/Common Operating Picture

- Interaction between small UAS, eVTOL, and traditional that's interesting. Figure out how piloted and unpiloted vehicles interact in places like near buildings with something like a shared data platform. Will want ADS-B so you can see the drone. Next step is shared data services where routing is metered. The shared data platform will show when a drone is scheduled to be in the same area as an eVTOL.
- Requires shared infrastructure and without sharing data, it doesn't work.
- Some means of mutual situational awareness. Deconfliction algorithms can be advanced, but concept is information sharing – flight path, intent, priority.
- Main problem is not communicating the core telemetry data to each other. It's like different airlines building their own ATC. Before we can get to a USS that works, these people have to communicate with each other.
- Fly flight plan, everyone knows your intent. Flight following, system monitors and intermediately deconflicts.
- When Network Remote ID was dropped – that could have been a step toward inter-USS communication. Went they went for Broadcast, was a blow to getting everyone talking.

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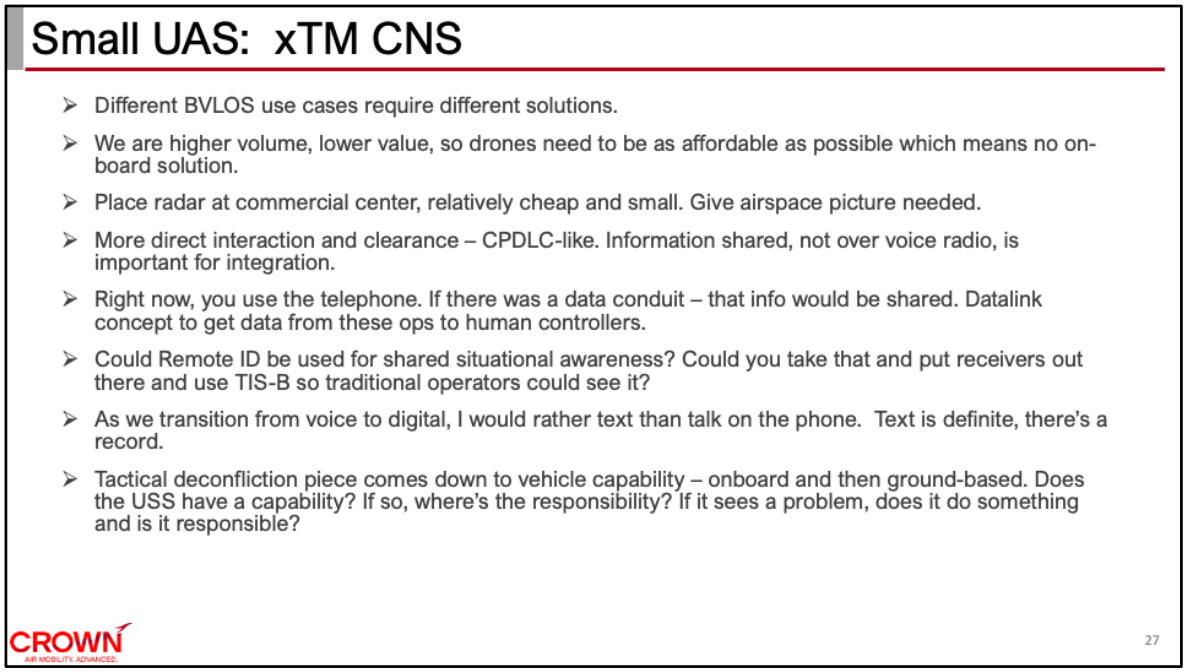
For shared intent and a common operating picture, everyone agreed that they needed to see each other and be aware of the operations.



For CNS, we are talking about the various kind of equipment and services they would want, one thing that came across is companies wanting some form of data link as opposed to voice. This surfaced several times in the interviews.

Small UAS: xTM Off-Nominal

- For off-nominal, model would be exception management.
- Flag those ops that controlling entities would see those and not the others. Then, in the future, when you get to air taxi operating in controlled airspace, mode C rings is where the bread and butter will be. Will have to be a more integrated model where exception is more the norm.
- As a part 135 operator, worse case scenario you have to contact closest facility and advise of emergency. That's the way it is now. Establish comm with local entity.
- Flyaway would mean a lot of things failed. If flyaway happens, it'd be a manual process of calling ATC and letting them know. UTM would be extremely valuable in those cases, albeit very rare.
- For eVTOL, at least in the beginning, it'll have a pilot on board. So, they push a button [to talk with ATC].
- The machine [aircraft] can interact with UTM and do separation. The human is over it and monitoring.
- Autonomous drones are highly reliable, don't depend on the C2 links.
- Future state might have less of a concern with fly-away or other off-nominal situations.
- For non-cooperative traffic, ATC interactions would take place.
- Alerts to ATC would come if there was something off-nominal but interactions don't go beyond the tower communications usually.
- There could be automation for the USS alerting the ATC if there is a non-conformance.

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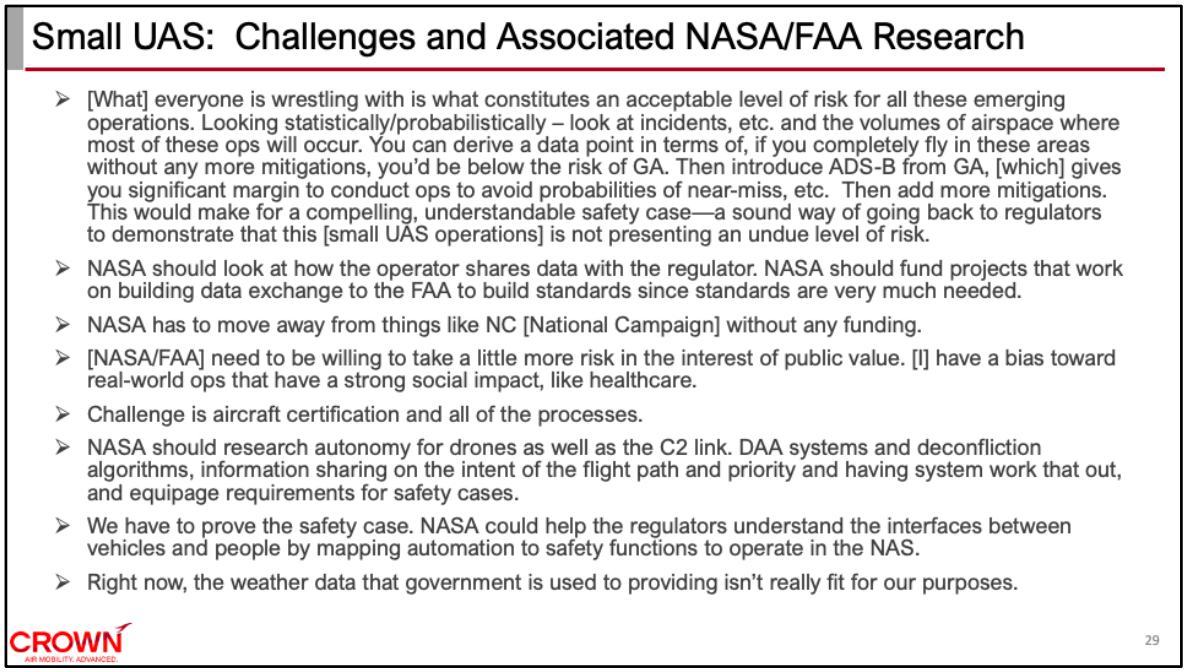
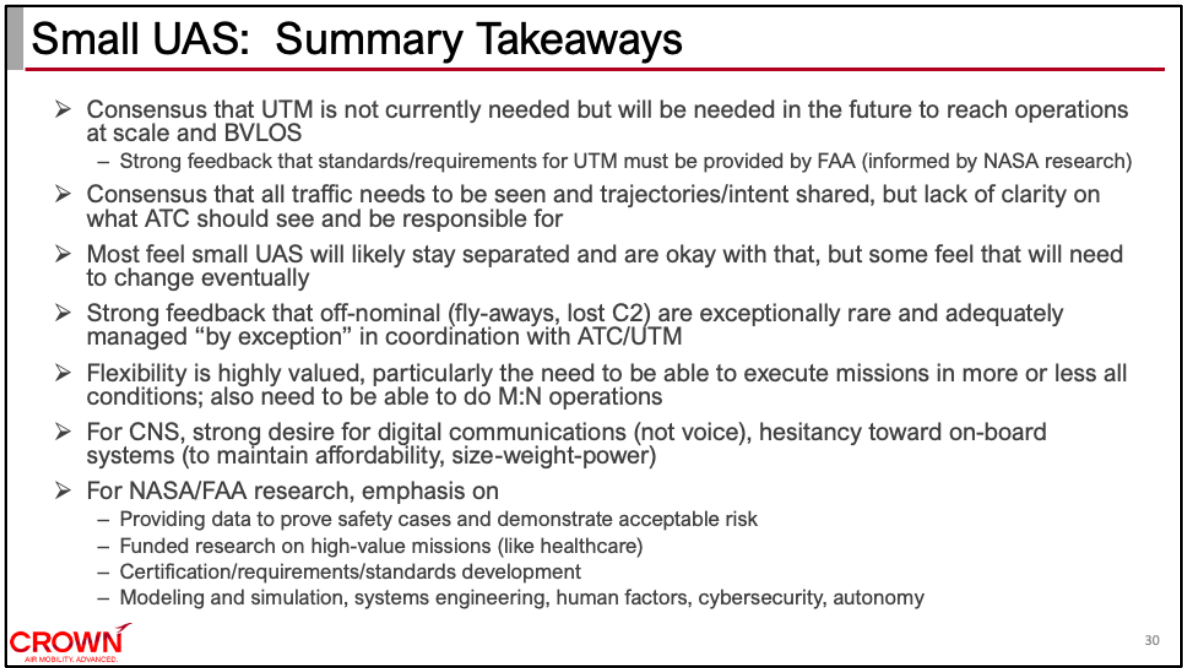
We got a prevailing expression, for off nominal, that these are very rare.



To highlight a theme, companies mentioned the struggle of getting the acceptable level of risk and that NASA could help by collecting the data on the acceptable level of risk.



What we could summarize from sUAS is that the interviewees talked a lot about not seeing the value of UTM now but when UASs scale it will be needed to see what other operators are doing. We had a lot of takeaways regarding separation and integration and that off-nominal operations should be managed by exception and in coordination with ATC.


Large UAS

Large UAS Companies Interviewed

- **General Atomics**
  - Leading manufacturer of Remotely Piloted Aircraft (RPA) systems, radars, and electro-optic and related mission systems solutions specifically their Predator series of aircraft for multi-mission remotely piloted aircraft.
- **ICAO RPAS**
  - The Remotely Piloted Aircraft Systems Panel (RPASP) coordinates and develops ICAO Standards and Recommended Practices (SARPs), Procedures and Guidance material for remotely piloted aircraft systems (RPAS), to facilitate a safe, secure and efficient integration of remotely piloted aircraft (RPA) into non-segregated airspace and aerodromes.

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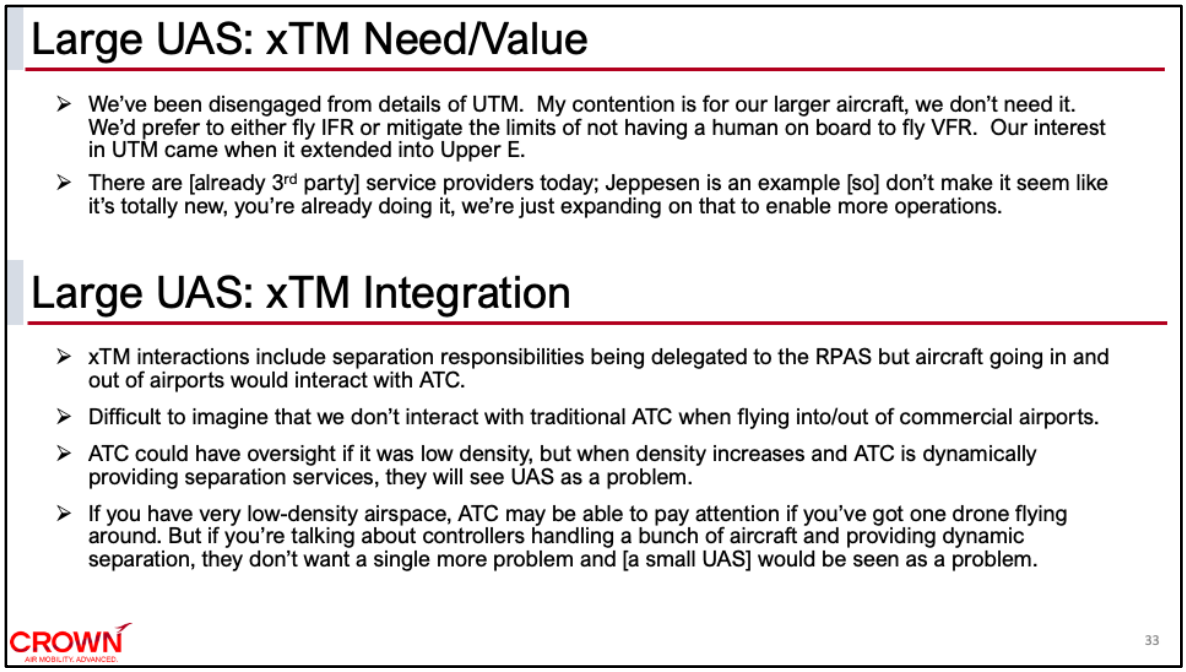
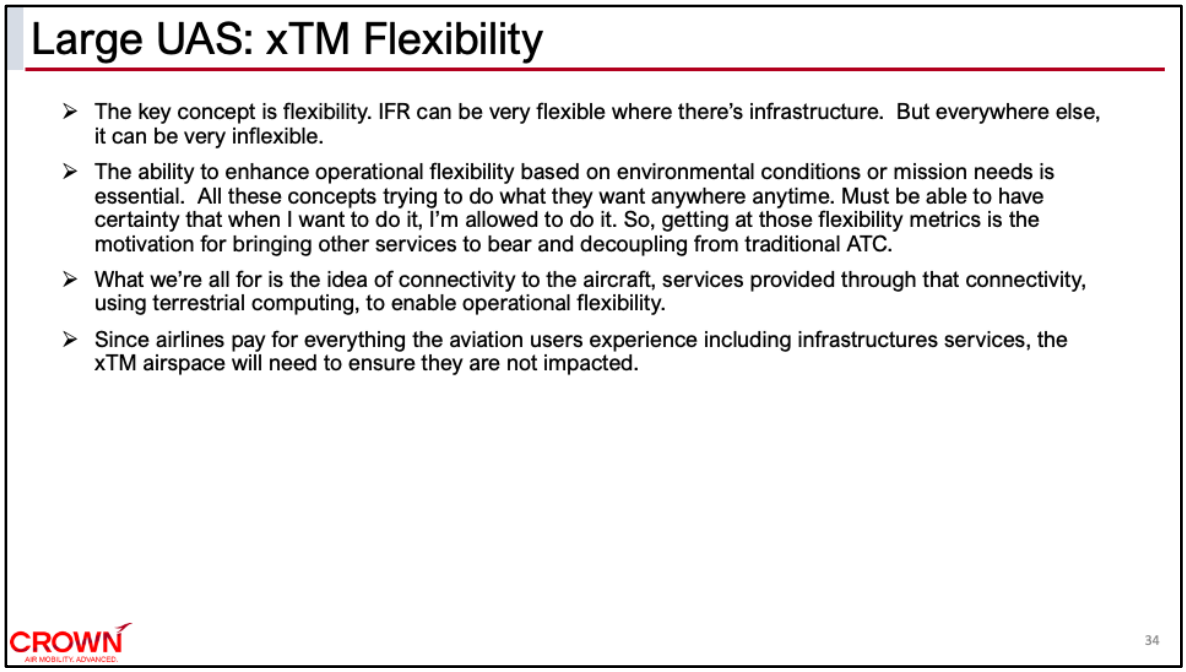
We have brief descriptions of each of the companies interviewed at the front of each section for awareness.



For larger UAS, UTM might not make sense compared to the sUAS. When we talked about having third-party service providers, they cited Jeppesen as a precedent. For integration, they were much more aligned with integrating and being looked at as pretty much any other aircraft with no special treatment.



There was a recognition of the dominant airspace user of commercial airlines and that whatever is developed for xTM and ATC coordination will need to not impact the commercial airlines.

Large UAS: xTM Shared Intent/Common Operating Picture

- Controller needs to know if something is happening in their airspace.
- With AAM likely to start in same airspace as drones and then come into ATC-controlled airspace, how does the controller find out about that? How does the information get conveyed?

Large UAS: xTM CNS

- For RPAS, you won't get airborne without a C2 service provider—either yourself or a 3rd party

Large UAS: Off-nominal

- [no comments made]

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Large UAS: Challenges and Associated NASA/FAA Research

- Regulatory challenge is that FAA doesn't have way to qualify/authorize 3rd party service providers in general. No equivalent to aircraft type certification for service providers or ground-based infrastructure providers.
- NASA has done well on architecture and framework, hardcore systems engineering work. That work is important. Interoperability is something NASA is uniquely positioned to do. Cybersecurity is the 800-pound gorilla in the room.
- The LVCDE capabilities need to be considered as important as wind tunnels were back in the 40s and 50s. Consider them national infrastructure assets, just as important.
- Community needs help on the human factors side and integration aspects. No company can bring all that together and do integrated studies like NASA can. Keep going, expand those capabilities.
- The service provider piece of the xTM thing, is not particularly sexy – aircraft capture imagination (eVTOL, supersonic, etc.). So, service provider piece which is equally important, is going to be difficult for those companies to get level of investment needed. Nation-state levels of resources, not venture capital. May need NASA to make more direct investment, direct funding to actually stand up and get safety critical 3rd party service providers going and then let private financing take them to scale.
- Look at airworthiness of the aircraft (UAS) and how it operates in the system. Is it something where we can work with the industry standards development organizations to develop technical industry standards that address airworthiness?

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When we asked about challenges and associated NASA/FAA research, there was the encouragement that NASA needs to continue doing what they are doing specifically in systems engineering and cybersecurity. The companies were saying that there is focus on the vehicle part, everyone loves the aircraft, but when you get to other services, it is not as appealing to work out. It will still require a ton of resources as this person says, national or state level of resources not venture capital to accomplish what is needed.

Large UAS: Summary Takeaways

- Consensus that all traffic needs to be seen and trajectories/intent shared, but lack of clarity on what ATC should see and be responsible for
  - Specifically highlighted the need for ATM interaction in and out of commercial airports
- Large UAS (RPAS) strive to be treated as any other (crewed) aircraft and integrate fully
- Operational flexibility based on environmental conditions or mission needs is essential
  - IFR can be very flexible where there's infrastructure but can be very inflexible elsewhere
- For CNS, highlighted the need for a C2 service provider
- For NASA/FAA research, emphasis on
  - Providing data to prove safety cases and demonstrate acceptable risk
  - Certification/requirements/standards development
  - Foster 3rd party service providers
  - Building upon existing NASA capabilities like LVC-DE, human factors, cybersecurity, autonomy

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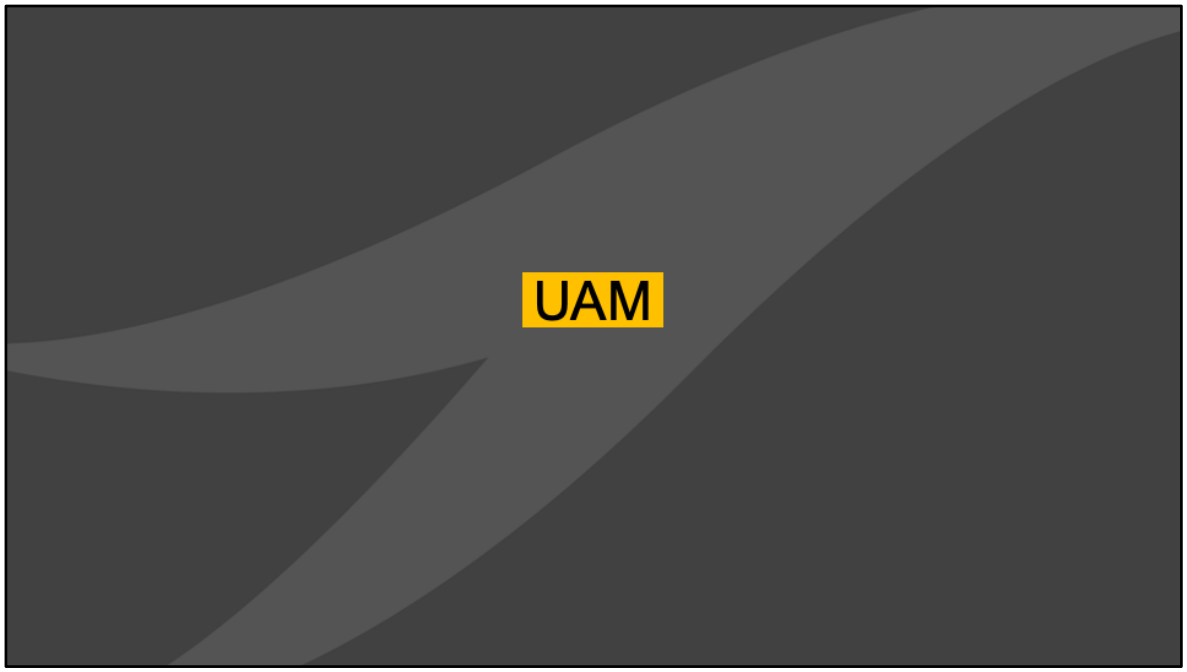
UAM

UAM Companies Interviewed (1 of 2)

- **Aurora Flight Sciences**
  - Aurora is collaborating with Wisk in the development of their air taxi design, researching the future of UAM and how that extends into urban traffic of the airspace, and utilizes their passenger air vehicle (PAV) prototype to inform design decisions for autonomy, electric propulsion, and battery technology.
- **Boeing**
  - Boeing is partnered with Wisk and Aurora Flight Sciences in the development of Wisk's Air Taxi and Aurora's technology solutions for UAM.
- **Elroy Air**
  - Elroy Air's mission is to enable same-day shipping to every person on the planet with Advanced Autonomous Cargo Aircraft (hybrid-electric VTOL vehicle named Chaparral which can carry 300lbs of cargo for 300 miles).
- **Jaunt**
  - Jaunt's mission is to change the way people commute by developing a passenger carrying air taxi with slowed rotor compound technology. The patented technology in combination with a small wing sized for cruise produces a lift to draft ration equivalent to a fixed wing airplane.
- **Joby**
  - Joby is designing an all-electric aircraft to take off and land vertically. The aircraft will travel 150+ miles on a single charge, allowing a pilot and four passengers to leapfrog over the congestion below, emissions-free. Planning to begin commercial flights in 2024.

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We have brief descriptions of each of the companies interviewed at the front of each section for awareness.

UAM Companies Interviewed (2 of 2)

- **Lilium**
  - Lilium's vision is to create a sustainable and accessible mode of high-speed, regional transportation. Using the 7-Seater Lilium Jet, an electric vertical take-off and landing jet, offering leading capacity, low noise and high performance, Lilium is building a transport network and service for people and goods.
- **Reliable Robotics**
  - Reliable Robotics is focused on advanced automation to transform the way goods and people move around the planet. Starting with a certification-forward approach, Reliable Robotics first demonstrated gate-to-gate fully automated operation of a Part 23 aircraft and is now working towards commercialization of technologies for Part 23 cargo and Part 25 passenger vehicles.
- **Wisk**
  - Wisk is an UAM company primarily focused on urban taxi operations. Wisk is participating in the NC and working with vertiports to foster the industry and define the standards.
- **Xwing**
  - Xwing is focused on building autonomous technologies on CTOL aircraft to build a smart air mobility system. They are converting leading cargo aircraft into remotely-operated airplanes so every regional route can be serviced reliably to improve access to goods.

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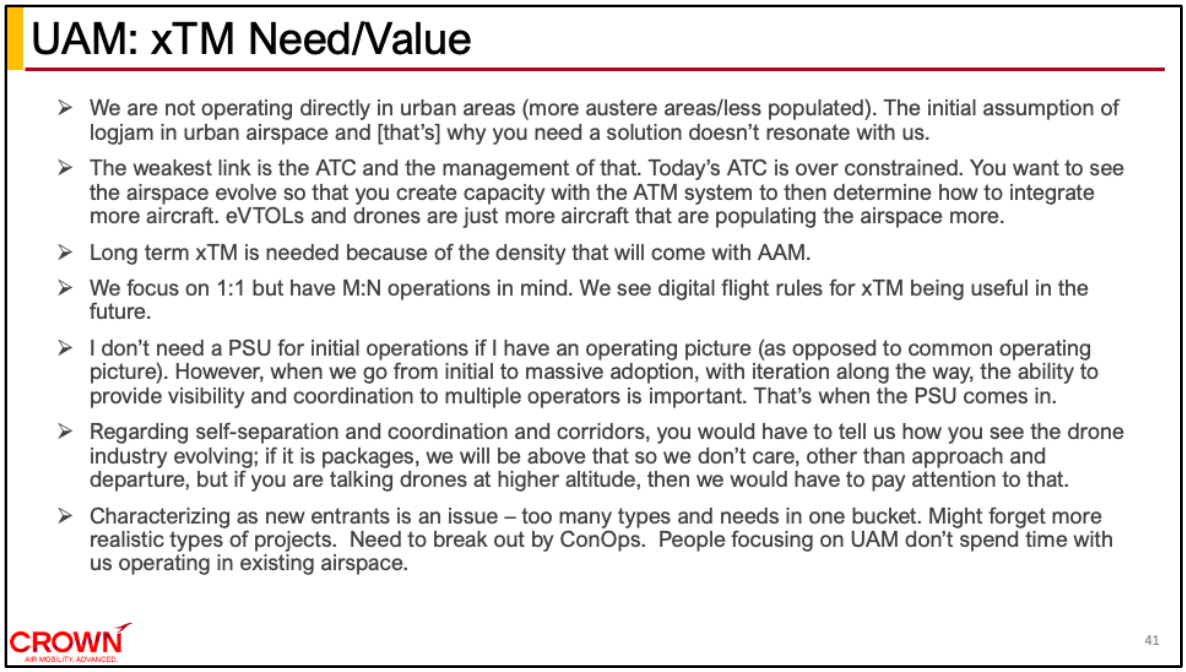
We have brief descriptions of each of the companies interviewed at the front of each section for awareness.



For the need and value aspect, with UAM there is a little bit of an analogue similar to what we heard about UTM from the UAS people--they said they don't need the PSU immediately, but when things scale up, they want the PSU.
One interesting point was the tie-in to drones (second to last quote).
Another interesting one is the last quote -- this person was vocal about xTM and it being focused on new entrants. There are a lot of different things that go into that, this person was making that a point not to draw conclusions and be cautious because there are so many different things going on.

UAM: xTM Integration (1 of 2)

- There's segregated airspace and segregated operations. GA is in the same airspace, but GA pilot doesn't want to deal with eVTOL when they can just go over them. Operational segregation works when you don't impact the other users.
- They are saying the operations are non-segregated, but in practice they are. We need to create airspaces with limited scope in terms of how they'll behave and allow ATC to say, "you don't need me, I'm not responsible." UAM can work by carving out airspace or operations and creating opportunity for the external management functions/services.
- eVTOLs will be in streams between vertiports so if regular users aren't being denied airspace they need, [the eVTOLs] will be the main users. Then you can operationally segregate, almost like a daily NOTAM.
- Doesn't make sense for a typical ATC to manage traditional traffic and also manage inner city traffic. It doesn't have to be a PSU but feel it needs to be a different person because of the different performance characteristics of the aircraft [the UAM aircraft].
- Once you have people on board, from a safety perspective, it seems like you need it to be handled by an air traffic controller, though I know not all companies are thinking like that.
- One main difference with NASA UML-4 landscape is we would not be looking at dynamic routing as the end state to allow us to operate at scale – we're targeting fixed route networks as a means of removing some complexity involved with dynamic routing. We believe to certify with fixed routes is a way to reduce risk further.

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A lot of comments on operational segregation. On interesting one is in the last quote -- this company made the point that when they look at what NASA published for dynamic routing, they said they are going through fixed routes at first to remove complexity.

UAM: xTM Integration (2 of 2)

- Hope to file IFR flight plans and integrate from an ATC perspective no differently than other aircraft.
- Drones should not be segregated, and technology needs to get to the point where they can be detected.
- There are pros and cons with corridors. Tend to think about segregated airspace but not quite sure how we go from today to these corridors. Segregation of aircraft is probably not generally a good thing.
- Currently we operate in VFR but have the capability for IFR and it is critical we get to the higher densities in VFR and IFR airspace by leveraging the ability to have specific kind of spacing differences based on equipage. We are looking at an integrated model into the airspace. See us mostly with other GA, well above 500 ft of UAS.
- We do not see a need for the airspace to change. In an ideal world, any given ATC wouldn't even know that we were an unmanned vehicle or a remotely operated vehicle. We don't need special treatment or to fundamentally rethink the interaction in the NAS currently.
- Segregation model that small UAS is using is not feasible for us.
- We're developing piloted aircraft. Equipped with everything allow us to operate in controlled and uncontrolled airspace. Fairly conventional VFR at first scaled to IFR operations. We typically fly through all airspaces up until 10,000 ft. Part 135 operation.
- First years of operations, very traditional ATM-ATC integration.

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Most UAM OEMs said that they want to be treated like any other airplane, some even said that drones shouldn't be segregated but that everyone should be detected and seen. "Segregation is not generally a good thing" and "segregation is not feasible", we received a lot of that kind of feedback. Integration was looked at as the goal.

UAM: xTM Flexibility

- The key is preserving flexibility. We're already in a federated environment – in VFR, pilot is responsible for providing their own separation, etc. Don't add additional requirements that restrict flexibility.

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UAM: xTM Shared Intent/Common Operating Picture

- If we're talking about airspace management, all of these have a common operating picture need. Autonomous flight rules/"AFR" traffic wouldn't be viable with mixed traffic in regular airspace management.
- The more you can share advanced knowledge of what the aircraft wants to do, the better. We need to share intent data like energy state data, emergency landing site data, etc.
- Rather than trying to equip every single vehicle in the NAS to see other aircraft, it might make more sense to have a centralized system that has a complete understanding of the traffic in the airspace and broadcast that to everyone to use that openly.
- We agree with using APIs to share trajectories. The technology would monitor the aircraft and send commands and talk to ATC.

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Third quote: some thought about a centralized system which was a different perspective that we didn't hear from anyone else.

UAM: xTM CNS

- The aircraft must be equipped with everything that's required (conventional). The biggest difference is the lack of the data link. With increasing automation, it would be in our interest to increase data communication.
- Key functions of the pilot – aviate and communicate. We're separating those from the aircraft. In the air, double-standard of FAA burden for unmanned vs manned. For IFR, don't have to do much, radar separated. That doesn't seem to be afforded to unmanned. Need system on aircraft with sensors.
- In addition to DAA looking forward and backward, we have burden of clearing airspace volume above and below (aircraft, birds, whatever). Linking that to some radar-controlled instrument flight plan, not super straight forward.
- We see automation progressing. One pilot per aircraft, established network. This can move to one pilot controlling two aircraft because it becomes more routine. Technology that supports that is data link (what CPDLC was supposed to be). Voice link stands in the way. Maybe could handle two but breaks down after that. For routine ops, one pilot can babysit 2-5 aircraft. Communication will come through a data link.
- Lagging areas are communication with ATC, minimizing the separation with more technology, and faster detection and avoidance.
- People are trying to get to certification with C2, but whether the standards are there or not, we need the communication link with integrity, etc.
- For autonomy to take hold, an aspect we'd need is a structured digital communication that can be automated to be more pervasive. However, we can't divorce from voice communications yet.

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For CNS, you will see a few different things captured in the interviewee's comments. One thing that many pointed out was the concept of needing datalink. A lot focused on digital communication rather than the voice comm link.

UAM: xTM Off-Nominal

- If you need to land an eVTOL at a regular airport/runway, then you would need to interact to declare an emergency but that should be a rare case.
- There is a lot of emphasis on unmanned aircraft when there is a GPS outage. That is a contingency that is baked into the FARs and you switch to radio navigation. You could do that in our unmanned aircraft, but you cannot do the terminal phase of coming in for a landing and knowing where you are relative to the landing area.
- If we assume that we are still dependent on the air traffic controller, in case of communication loss, we would have disconnected zones in airspace if there is a loss of communication to central air traffic controller.
- ATC will have access to seeing the operations on their screens. If there is a contingency, ATC should have the information via the technology on the aircraft to automatically reroute. ATC should see my plane, see my plans, etc. If I lose my engine, they should see that on their screen.
- We need to reach the level of 10 to the -9 to reach airliner levels.

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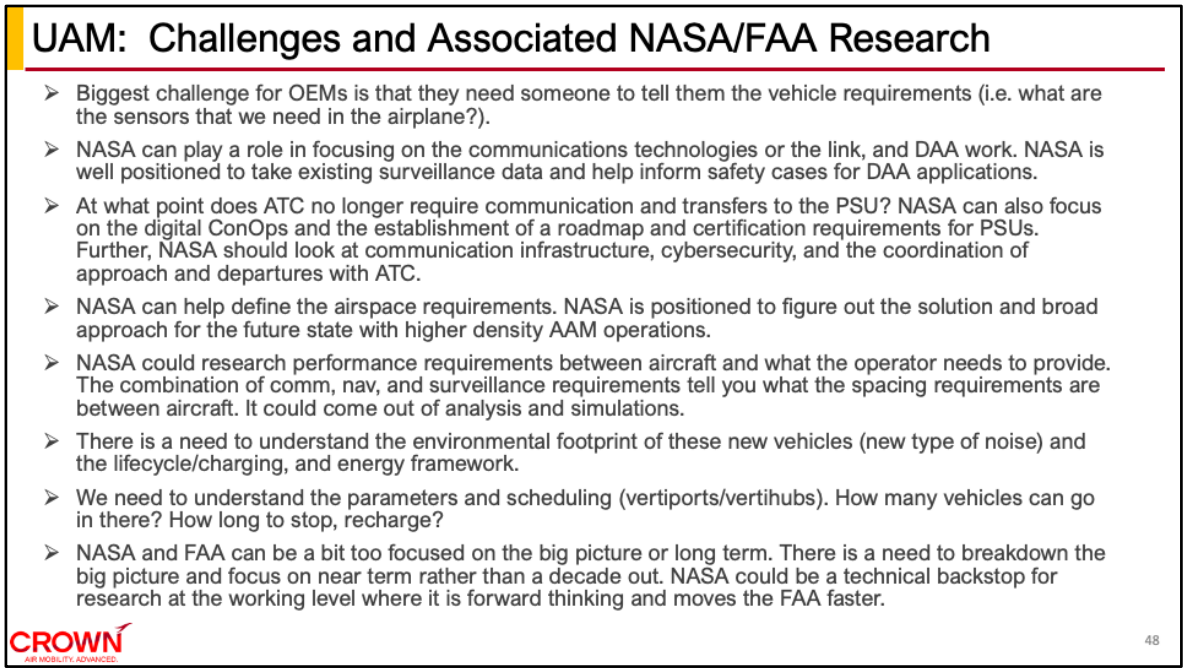
For off nominal, the UAM is carrying passengers, so off-nominal cases become more acutely important.



One thing that came up a lot for research areas is setting requirements – as seen in the first quote (vehicle requirements), third quote (PSU certification requirements), fourth quote (airspace requirements), and fifth quote.

The other interesting quote was the last one where this interviewee encouraged the government to not just look at the long-term. This is because companies are focused on surviving in the near-term.

UAM: Summary Takeaways

- Recognition of the need to evolve ATC to an xTM service (e.g., PSU) to manage the over-constrained airspace that will continue to grow with drones and eVTOLs
  - But some companies are not targeting busy urban airspace and thus do not see the same need for xTM
- Not all "new entrants" are the same; many different use cases and objectives
- Consensus that there is a need to share trajectories/intent, but different thoughts on how to achieve that (centralized versus distributed to each vehicle)
- Preference expressed for segregated operations in the same airspace
  - Mixed opinions on corridors and dynamic routing versus fixed route networks
- Off-nominal conditions are considered to be understood and manageable, but there would be a need for coordination with ATC
- For CNS, feeling that
  - the requirements are greater for uncrewed aircraft versus crewed aircraft
  - digital communications are needed
  - need to get to M:N operations
- For NASA/FAA research, emphasis on
  - Requirements (vehicle, airspace, CNS)
  - Don't just focus on the far-term; near-term work is strongly desired to help this nascent industry

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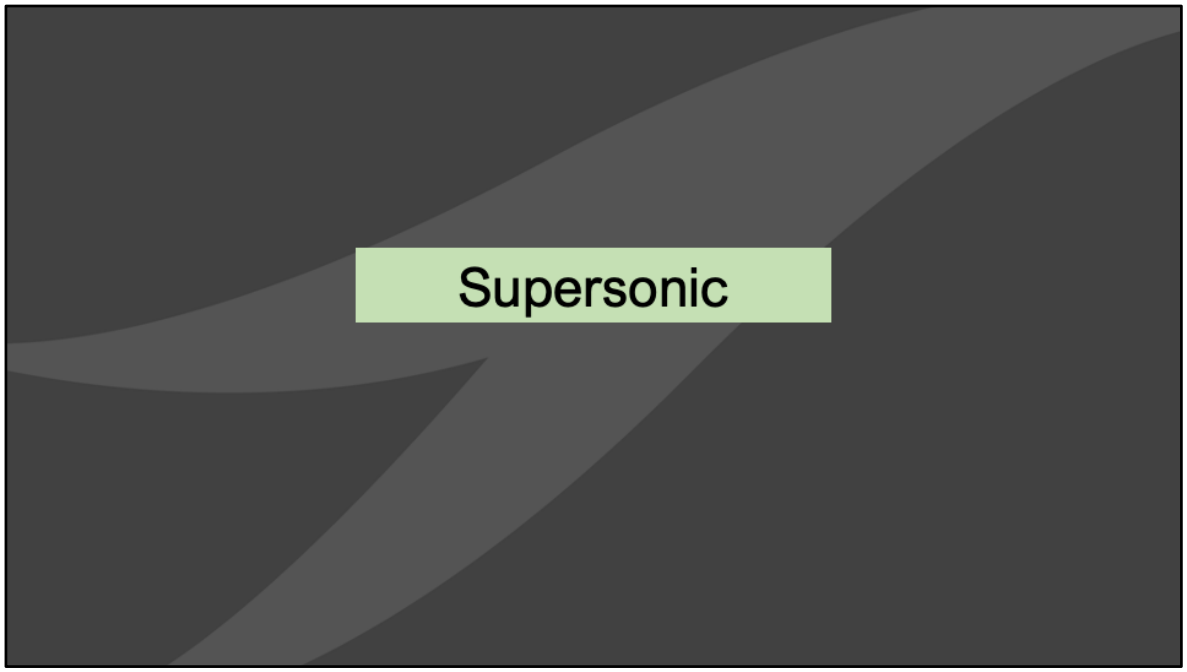
Supersonic

Supersonic Companies Interviewed

- **Boom Supersonic**
  - Building the fastest and most sustainable supersonic airliner to enable twice as fast flights to access the globe. Boom Supersonic is building on Concorde's legacy through faster, more efficient, and sustainable technology.

Note: *Because we only interviewed one Supersonic company, we are unable to provide the anonymity/non-attribution that we did for all the other interviewees. We explained this situation to Boom Supersonic and they have graciously given us permission to attribute their comments.*

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Boom is the only company for whom we could not maintain non-attribution and so we're grateful to them for providing permission to still use and report their input.

Supersonic: xTM Need/Value

- Our current design will not operate in Upper Class E; we had designs getting close to the 60K ft. mark, but we will be in the mid-50,000 ft operating in Class A.
- If we made an Overture 2.0 to go to the low 60s, for a commercial operator, they need something equivalent to today's class A, whether that means active radar monitoring or done by some other means. But some of the HALE concepts about negotiating space and all of that, I don't see how that will provide a level of safety equivalent to what we get today in the actively managed class A or the oceanic procedural airspace we have today.
- In addition to the safety concerns, it is unclear how a cooperative separation scheme would allow compliance with § 91.123, that requires compliance with ATC clearances absent an emergency or a TCAS resolution advisory.

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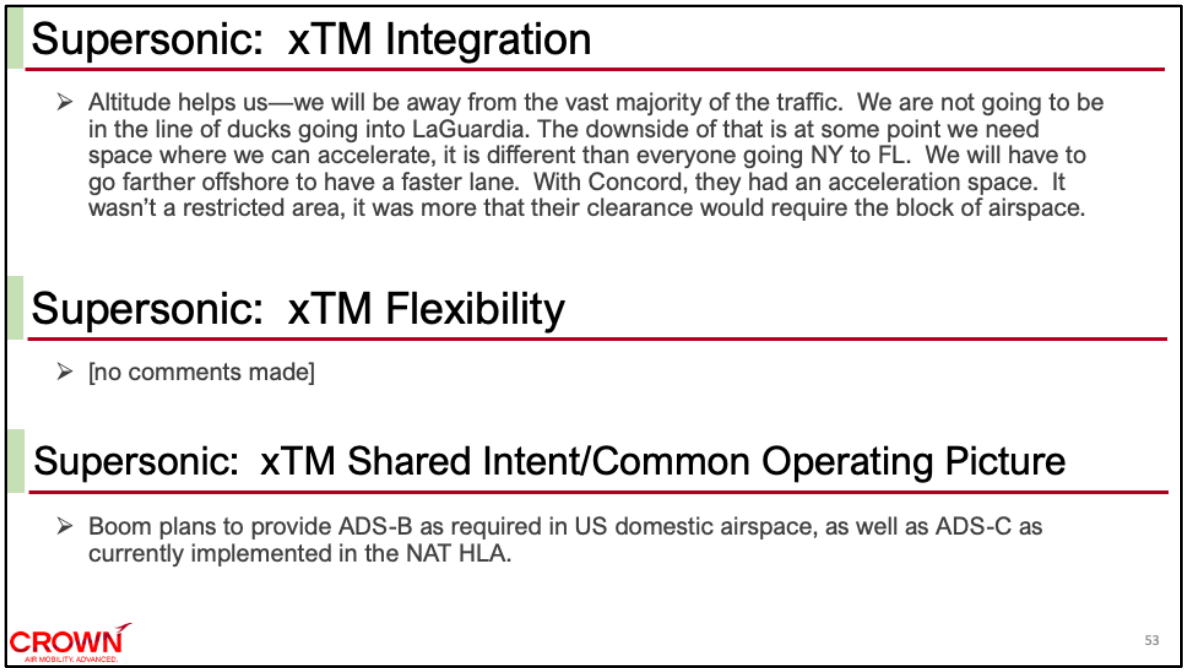
Boom was unique in the fact that they had already provided written input to NASA so at least some of the NASA folks may have seen this, but not sure if FAA has seen the feedback they provided.



For integration, HPAS and HALE mentioned supersonic, and they needed to consider how they would interact.

They are saying for most of the flight they will be separated but when they are near the airport that is a different story.

Supersonic: xTM CNS

- Boom anticipates that supersonic commercial airplanes will be equipped to meet the current standard of RNAV 2 for continental enroute routes and RNP4 for oceanic areas.
- Boom plans to implement some form of CPDLC as required by ATC providers or requested by operators.

Supersonic: xTM Off-nominal

- Boom believes that for normal, non-emergency changes to route clearance a heading/track change is preferable to a climb or descent.
- For non-normal, emergency collision avoidance, Boom believes that either the current TCAS system, or something equivalent, will be necessary to maintain the current level of safety in commercial aviation.
- A significant challenge for the system will be how the Upper Class E system will respond to a supersonic airplane as a conflict threat, such as when it needs to immediately deviate or descend.

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Boom said the same thing, if traffic is mixed, supersonics are something that needs to be accounted for (Upper E)

Supersonic: Challenges and Associated NASA/FAA Research

- RVSM approval will be necessary to permit compatible operation at lower altitudes during climb and descent. For flight above the current RVSM limits, it will be necessary for industry and the ATC providers to determine if extending the reduced separation limits from RVSM are cost-beneficial.

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Supersonic: Summary Takeaways

- Boom is planning to operate more-or-less as a traditional aircraft within traditional airspace
  - They do not plan to fly at the Upper Class E altitude, thus do not need ETM
  - They will be above most traditional traffic, most of the time, but need to integrate for takeoff/ascent and descent/landing and need additional space for those phases (not clear if xTM can help with those needs)
- Boom expressed concern about new concepts (xTM; specifically, ETM) that include cooperative/negotiated self-spacing amongst participants
  - Unclear to them how safety can be maintained on par with what is expected in Class A airspace, such as through active radar monitoring
  - Also unclear "how a cooperative separation scheme would allow compliance with § 91.123, that requires compliance with ATC clearances absent an emergency or a TCAS resolution advisory"
- Boom plans to equip with CPDLC
- Boom believes TCAS or a similar system is needed for safety
- Regarding future research needs, Boom mentioned the need to look at whether RVSM should be extended above the current upper flight level limit

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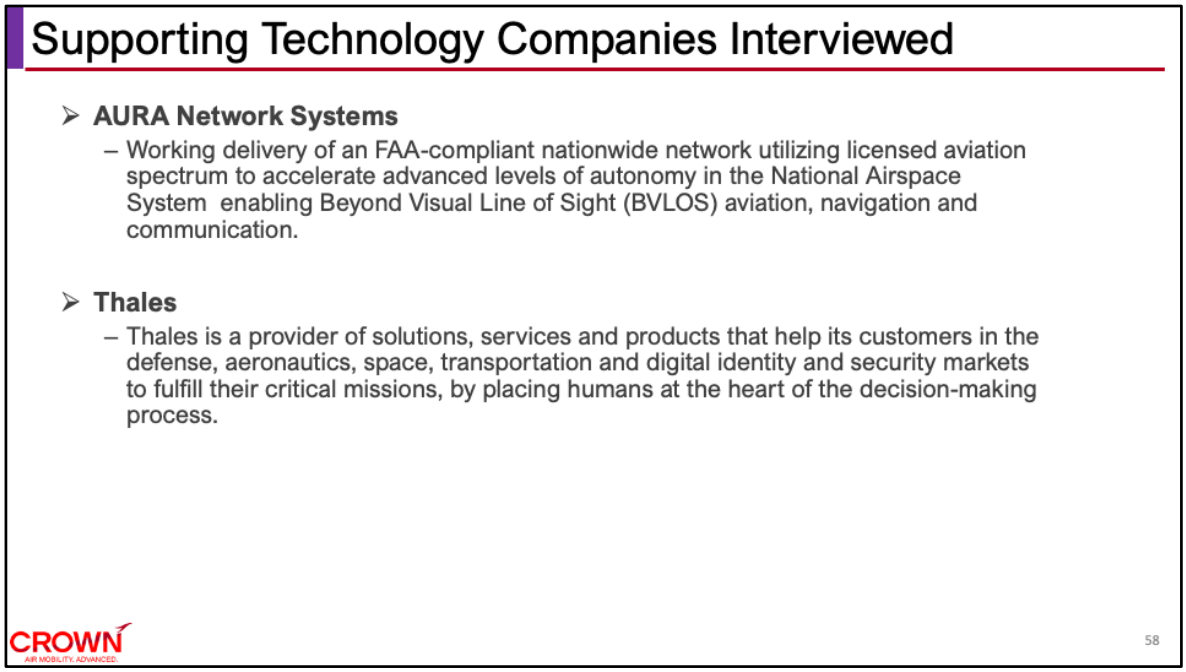
Supporting Technology



We have brief descriptions of each of the companies interviewed at the front of each section for awareness.

Supporting Technology: xTM Need/Value

- UTM was more of looking at a specific segment of the aviation ecosystem [small UAS] to push a new concept rather than looking at aviation as a system of systems and how everything needs to interact.

Supporting Technology: xTM Integration

- Having infrastructure that resembles something closer to aviation grades and standards that the FAA is accustomed to will allow states and municipalities to be more active participants in UAS integration at scale.
- Some ConOps that have been put out there for UAM is focused on segregated airspace by in large defining corridors or looking at airspace constructs that don't interfere with the current ATM system.
- We view this [segregation] and that approach [corridors] as a step wise function towards airspace integration, but it is not the ultimate end solution of true airspace integration

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For UTM, this supplier was saying it is a system of systems and UTM fits in that, but it is not covering the waterfront. For the integration aspect, it mirrors the earlier comments, but eventually you need integration although we may not start that way.

Supporting Technology: xTM Flexibility

- Aircraft and helicopters will have certain constraints for how they fly. It is very static (for the routes they have to fly) and when you look at drones, and even altitudes that are managed by the FAA today. A dynamic system is needed to handle that.

Supporting Technology: xTM Shared Intent/Common Operating Picture

- Bring together the aircraft and bring together the ANSPs and that has to be looked at holistically through that systems lens in order to safely and truly integrate the operations into the airspace.
- We need some sort of system to track. The guidance should be along the lines if you put on surveillance infrastructure, you could share information in the event of having an off-nominal scenario, rather than going on and procuring something where you're able to track and disable drones.
- There is an opportunity to look at data exchange between municipalities and the federal government and there are services that can be federated with the FAA providing checklists to be qualified, etc.

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For flexibility, not surprisingly, it was agreed that it was a good thing. Shared intent and common operating picture is more or less on the same wavelength as other categories. The last quote is a little bit of a new thought to coordinate at a local level with what the government is doing.

Supporting Technology: xTM CNS

- There is a need for ubiquitous communication capabilities.
- We are looking at a systems of system approach. Counter UAS and we have UTM on one side, and we view that as surveillance and whatever the technology is. How the surveillance information is being used by an operator for a mission purpose is what defines that function.

Supporting Technology: xTM Off-Nominal

- Operators will need to have capabilities in navigation functions with non-GPS solution.
- Aviation and ATC being a deeply routed safety culture and safety-first culture, it will take a definite tight rope and balance between the new technologies and approaches and applying the best practices and needed safety methodologies.
- The Safety and Risk management process, their procedures are clear on what FAA approval is needed to scale. That will deal with the off-nominal. As you go through the risk assessment, there is a way to deal with degradation of operations. If you lose a function on the aircraft, there is a degradation you walk through.

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For off-nominal, the big thing here is that they are really hammering that it is all about safety and getting to that safety level that aviation is now accustomed too.

Supporting Technology: Challenges and Associated NASA/FAA Research

- SBIR solicitation for digital comms. None of them are for aeronautics, they are all for space. That's a signal that digital comms for aeronautics and for NAS capabilities remain an afterthought or stepchild.
- What does it look like to have NASA establishment of communication infrastructure required initially for early adopters and new entrants, toward UML 4, 5, and 6? Including role NASA plays in FAA's ability to certify safety of flight.
- Need to have capabilities in navigation functions with non-GPS solution. PNT solution. Digital voice function.
- Require NASA's role in standards development. ATOL has played a role in standards development but over the years has been dialed back. Public private partnership, like AGATE, focused on digital comms. Cybersecurity for those digital comms, too.
- Needs to be role for NASA of leadership in formulating and operating a [government/industry] collaboration.
- One that comes to mind is interoperability, it is not only for the US but internationally. That is not traditional NASA research but could be an FAA topic that needs to be considered.
- Envision a future state of the airspace integration and what that looks like that may not be bound by our current definition. It is more of a free thinking thought exercise and understanding what that end goal looks like and that would go a long way to take the tangible first steps on moving things in the right direction.
- Challenges can be addressed from a variety of standpoints. There is uncertainty and that can be geared towards aircraft certification and what the services are that will be comprised at the federal level like the FAA's FIMS. Anything that is not in the FAA's realm of control is something they are not comfortable with and that takes on a whole new level of scrutiny.

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For research, there are things about digital comms in SBIRs, but it is on the space side, so this person was saying it makes it look like it is not as important for aeronautics, but it is. Standards development was called out which is a good one for NASA and FAA.

Supporting Technology: Summary Takeaways

- The integration of UAM and drones should be taken incrementally. For example, creating infrastructure that resembles something closer to aviation grade and standards that the FAA is accustomed to.
- A segregated approach of defining corridors and looking at airspace constructs that will not interfere with current ATM system can be taken as a step wise function towards airspace integration.
- Strong emphasis on safety and safety culture
- For NASA/FAA research, emphasis on
  - Digital communications
  - Standards development
  - Aircraft certification

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Overall Summary Takeaways (Spanning All Company Types)

Overall Summary Takeaways (1 of 2)

- Lack of consensus on the need and value of xTM
  - Strong support for ETM
  - UTM not needed now but understood to be needed later
  - PSU situation mostly similar to UTM but even less defined
- Strong consensus on the need to share trajectories/intent to "see" all traffic
- Varying perspectives on the need/desire to operationally segregate or integrate the airspace, even within company types
  - Prevailing overall theme seems to be that segregation is a viable short-term approach, but the desire is to get to full integration
  - "Segregated operations" is preferred to segregated airspace; i.e., no airspace is strictly off-limits, but operators and service providers may choose to operate apart from others
- Consensus that off-nominal (emergency) conditions are both very rare and manageable by exception
- Consensus that flexibility is a priority but with differing connotations of that term

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At a high level we wanted to summarize all of what you heard throughout this briefing. The first one is the need and value because there are so many different use cases and flavors of xTM, you can't draw one high level of conclusion. For ETM there was strong support, UTM was clear that maybe not now but, and PSU was similar. Everyone across the board agreed on the need to share trajectories and intent.

The aspect of integration, whether there should be operational segregation or full integration, there were very different opinions, but we saw that the overall theme is segregation in the near term but that is not what it really should be in the far term.

Overall Summary Takeaways (2 of 2)

- Strong consensus on the need for digital communications
- Many areas cited for needed NASA/FAA research
  - Safety
  - Autonomy
  - Human Factors
  - Systems Engineering
  - Cybersecurity
  - Requirements and Standards
  - Certification
  - Focus on near-term, not just far-term

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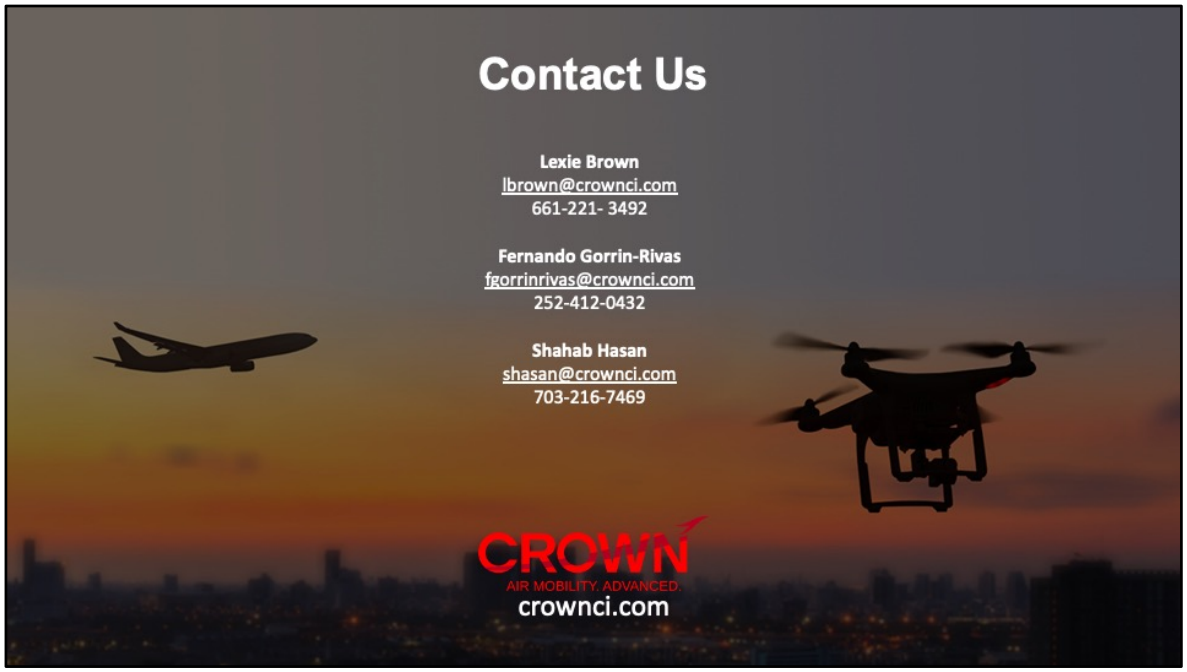
Contact Us
Lexie Brown
lbrown@crownci.com
661-221- 3492
Fernando Gorrin-Rivas
fgorrinrivas@crownci.com
252-412-0432
Shahab Hasan
shasan@crownci.com
703-216-7469
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